DOCUMENT RESUME

ED 454 050 SE 064 904

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TITLE Museum-College-School: A Collaborative Model for Science Teacher Preparation.

PUB DATE 2001-04-00

NOTE 24p.; Paper presented at the Annual Meeting of the American Educational Research Association (Seattle, WA, April 10-14, 2001).

PUB TYPE Reports - Descriptive (141) -- Reports - Research (143) -- Speeches/Meeting Papers (150)

EDRS PRICE MF01/PC01 Plus Postage.

DESCRIPTORS Higher Education; *Museums; Science Education; *Teacher Education

IDENTIFIERS American Museum of Natural History NY; City University of New York Brooklyn College

ABSTRACT

In the context of two summer courses (a science methods course and a geology course), the authors worked with 40 elementary and high school teachers enrolled in Brooklyn College's M.S.E. programs in elementary education or secondary science education. They were involved in different ways, in the teaching of these courses, the organization of a summer institute and other events for educators at the American Museum of Natural History in New York City, and the assessment of project impact on teacher participants and their classrooms. Two of them taught these courses, one represented the American Museum of Natural History and liased with the College as director of professional development at the Museum, while the other worked on assessing project impact by interviewing teacher participants to gain insight into their thinking and practice. (Contains 13 references.) (SAH)

Museum-College-School: A Collaborative Model for Science Teacher Preparation

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In the context of two summer courses (a science methods course and a geology course), we worked with 40 elementary and high school teachers enrolled in Brooklyn College's M.S.E. programs in elementary education or secondary science education. We were involved, in different ways, in the teaching of these courses, the organization of a summer institute and other events for educators at the American Museum of Natural History in New York City, and the assessment of project impact on teacher participants and their classrooms. Two of us (Eleanor and Wayne) taught these two courses, one of us (Maritza) represented the American Museum of Natural History and liased with the College in her role of director of professional development at the Museum, and one of us (Koshi) worked on assessing project impact by interviewing teacher participants to gain insight into their thinking and practice.

Informal-and Formal Science Settings

The American Association for the Advancement of Science (1990) urges science teachers to exploit the resources of the larger community beyond the school since children learn from a wide range of sources: museums, television, movies, and so forth. Further, Brown and Campione (1994) posit that Vygotsky's zone of proximal development can include effects of cultural artifacts such as museum exhibits since the zone defines the distance between current levels of comprehension and levels that can be accomplished in collaboration with other people or powerful artifacts. Such artifacts function as mediational means, just as talk does, resulting in the appropriation of words and concepts. In addition, recent national commissions on teacher education recommend to "reinvent teacher preparation and professional development for teachers to have continuous access to the latest knowledge about teaching and learning" (National Commission on Teaching & America's Future, 1996).

Science teachers in urban schools frequently feel the pinch of insufficient resources and yet science museums in the same urban settings are rich in recent research and in primary source materials placed in their real-world context. These methods, ideas, and artifacts have the potential to help students understand scientific ideas or phenomena. It, therefore, seems natural to hope for a connection between museums, teacher preparation, and classrooms. However, it also seems to be the case that simply introducing science classes to museums is not an effective teaching strategy to reach these goals. Professional collaborations that join teacher educators, museum scientists and practicing teachers in the professional development of teachers tend to do the following three things: model for teachers how scientists and educators use the museum in their work, provide teacher educators with a new setting where they can teach in addition to the college classroom, and help teachers to engage in thoughtful study and discussion of how to use museums for solidifying their knowledge of science and of how to use museums as a curriculum resource for teaching science in the classroom. In essence, this paper is about scientists, teacher educators, and teachers using the museum for their work and for teaching in classrooms.

We draw upon the perspectives of postpositivist philosophers of science and critical science educators who have problematized the nature of science and science education to think about the relationship between formal and informal science education. If we see our students' educations as works-in-progress, curriculum needs to ensure greater continuity in students' experiences as they move from classroom to beyond (Lemke, 2001). If we want students to bring themselves into the classroom, as opposed to practicing the "cognitive apartheid" referred to by Cobern (1996), then we need to find ways for their worldviews to have access to classroom agendas. Inclusion of meaningful, informal science experiences in classroom conversation is one strategy that encourages more students to participate in the conversation (Dhingra, 1999). Science is viewed as being inclusive and relevant as opposed to exclusive and unrelated to students' lives when the curriculum extends beyond the classroom in meaningful ways.

In order for teachers to accept and integrate new approaches and practices, they should be involved substantially with the reform effort, which involves partnerships between teachers,

researchers, administrators, and educators (Van Driel, et. al., 2001). Museum-school partnerships constitute effective agents for reforming science education (Ingram, 1999). However, in the absence of effective teacher education with a focus on the power of informal science learning experiences and learning experiences in the museum context, museum-school partnerships frequently end up being no more than field trips that are somewhat unconnected to the classroom curriculum. Looking at science education as a process that extends beyond the classroom, recognizing the rich resources available in the form of museums, and also recognizing that using these resources effectively requires thoughtful preparation, are professional practices that constitute an important type of science educational reform. To this end, a collaboration between the museum, college and schools, or teachers, seems necessary.

Museum-School of Education Collaborations

Of all informal science learning sites, the museum field has produced the most substantial number of research studies (Crane in Crane et. al., 1994). However, few studies have focused upon the links that exist between formal school settings and informal educational setting of the museum. As an example, one such partnership involved the University of Central Florida's College of Education collaboration with the Orlando Science Center in which preservice middle/high school science and mathematics teachers were required to complete half of their junior internship (7 weeks) in the informal learning environment of the science center. Emphasis at the Science Center was placed on the development of content and pedagogical skills in informal science and mathematics teaching and learning (Sweeney, 2000). Other collaborations with museums involving teacher education included School District 24 in the borough of Queens in New York and the Asia Society. Here, a planning session involving teachers, and school and museum administrators was seen as a critical step in the process (Piro, 1997).

Anderson (2000) posits that it is important that the relationships between the three key players be recognized, namely, the teacher, student, and the center or museum. The greater the overlap between these three domains, the greater the interaction between them, and hence the greater the mutual importance for teaching and learning science.

The educator Kenneth Brufee wrote: "We live in a period of necessary interdependence. It is through joint activities and partnerships that we confront our shifting realities and search for new solutions. This historical and technological context promotes collaboration in science, artistic endeavors, universities, industrial settings, and schools." (John-Steiner, 2000)

The American Museum of Natural History

The American Museum of Natural History is a scientific research institution with 200 scientists who participate in about 100 research expeditions a year, and houses 35 million artifacts and specimens. For the past 50 years the Museum has been engaged in different aspects of formal and informal teacher enrichment but in the past three years it has initiated a series of formal collaborations with public and private science teacher preparation programs to address two needs: expand the access of science resources to colleges and schools, and to partake formally in the systemic initiatives that join science rich institutions, teacher preparation programs, and schools in urban settings.

One of the central collaborations is between the museum and the teacher education programs in the CUNY (City University of New York) system. The collaborations seem to be taking different shapes according to the needs of the various campuses. At some colleges the collaboration takes the form of courses developed and taught by Museum staff to science teachers, in others the collaboration consists of college students participating in the summer institutes at the museum, and in others it has been a combination of participation in summer

institutes that is followed by courses taught by college faculties at the museum or back at the campuses - after the institute. This last model is documented in this preliminary research.

The goal of the Institutes is to bring current scientific research to an adult public audience. The strategies used reflect informal science strategies rather than a structured course. The Museum expects participants to interact with scientists, ask about their work, learn about their tools, and understand how the exhibits reflect the scientific content under study. As an informal experience, institutes are different from courses in that they operate more like mini-conferences. Participants choose which sessions they wish to attend, keynote addresses stress the scientific content, and the resources and memberships are made available to everyone, regardless of the grade level that they teach. Summer institutes for educators at the American Museum of Natural History are 15-18 hours in length and expand over three days. Faculty includes scientists, experienced teachers, and museum educators. Keynote speakers include scientists, college faculty, and board of education representatives. The audience consists of college faculty interested in including museums in their courses, graduate level college students preparing to be science teachers, and in-service science teachers. The purpose of the first day is to introduce participants to the research work of museum scientists and to the exhibits that present their work to the public. Museum scientists are expected to share their work with the public in two ways: developing exhibits that inform, educate, and enrich the public's knowledge in particular areas, and infuse educational programs with their expertise and presence. Each year, there is a different scientific focus. In 1998 it was Life Sciences with a focus on Biodiversity and Health. In 1999 it focused on Earth Sciences and in 2000 it focused on Space and Earth Science to celebrate the opening of the New Rose Center for Earth and Space and its Department of Astrophysics. Thus, the first day of any of the institutes begins with the scientists sharing their research using the museum exhibits. Copies of recent publications and documentaries of their work are made available to participants as a Museum resource for future use.

Second, institutes bring experienced teachers who do standards-aligned teaching and use the museum for supplementing their own knowledge and for teaching. These individuals do workshops that focus on methods for teaching content related to the institute. For example, in 2000 there were workshops on how to develop models of the Earth; models of the Solar System; using non-fiction earth and space science literature with various grade levels; and exploring concepts of Astrobiology. These presenters focus on content from the science standards that can be supplemented by resources from the museum. These presenters usually share how the museum exhibits or contact with the scientists has supported their own content knowledge and classroom curriculum.

Third, institutes provide participants with sample research trips to the Museum. Museum educators develop resources for guided study in the halls, discuss and demonstrate methods for using museum exhibits, and give participant background knowledge on the different exhibits through discussion and extensive packets of printed materials, films, and tools they can use in the classroom to prepare students to use the Museum. In addition, all institute participants receive a year membership to the museum. This membership is designed to make the museum available to teachers at any time they need to come and use it for supplementing their own knowledge or for planning to use it with their students. Museum memberships also make them recipients of invitations to special events, openings of new exhibits, discounted fees to scientific lectures and the shops.

Research Questions

In this study, we ask, first, how do two different museum experiences, both in the context of science education courses at the college, affect teacher learning of science concepts and related pedagogy? Both experiences involve a 3-day institute in earth / space science for educators held at the museum. One course experience involved the rest of the course being conducted at the

museum whilst the other involved the rest of the course being conducted back at the college. Second, how do the course instructors think about and evaluate their experiences in these courses? Third, to what extent does the museum-college collaboration affect teacher thinking and practice in the classroom?

In what follows, we describe three sets of perspectives in a collaboration that involved the American Museum of Natural History, the Brooklyn College School of Education, and in-service teacher participants in two different Brooklyn College courses that included summer institute experiences at the American Museum of Natural History. One of the course instructors (Eleanor) was in the School of Education and the other (Wayne) was in the Geology department at Brooklyn College. Methods used are summarized in Fig. 1.

Perspective as an Instructor in Science Methods

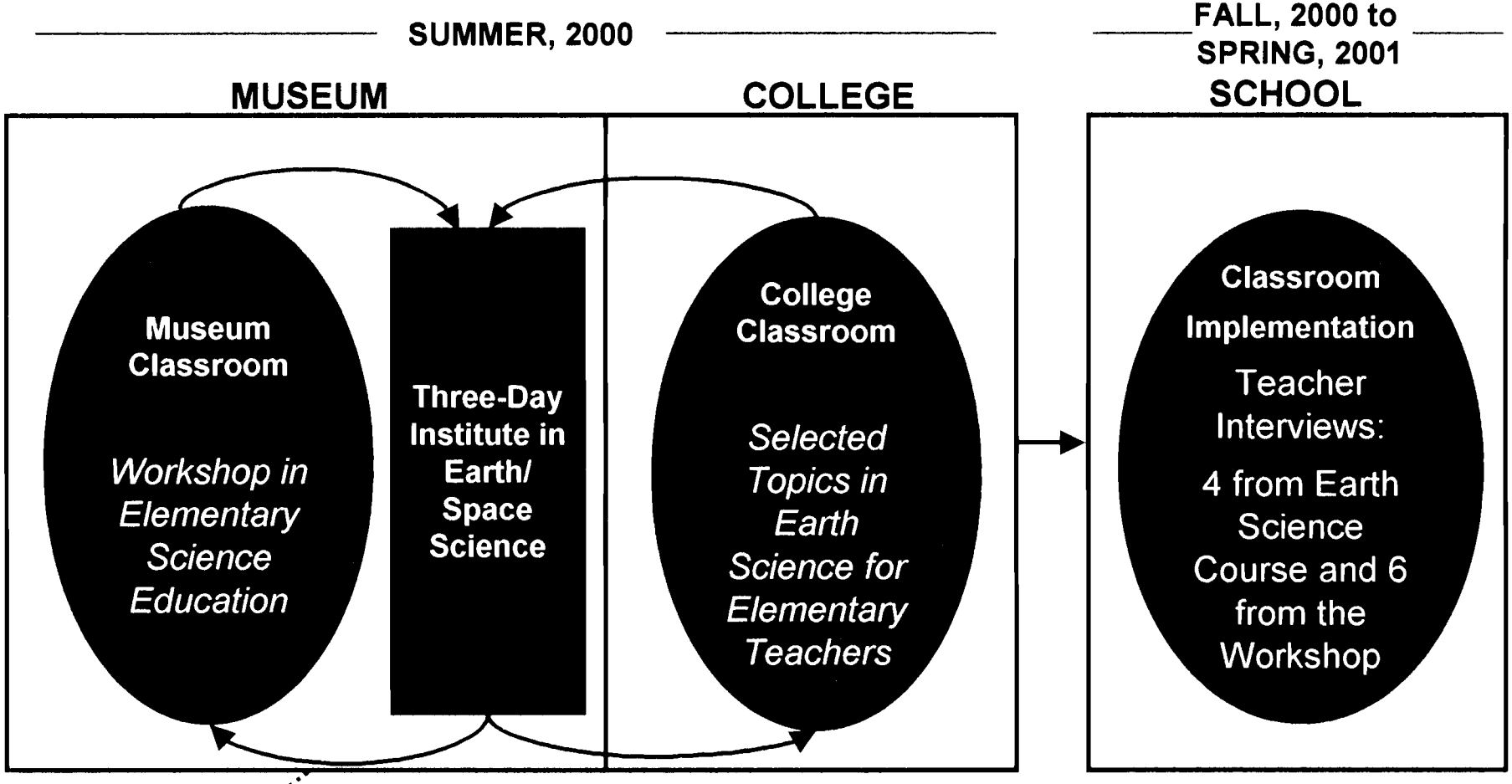
A science methods course called *Workshop in Elementary Education: Science* was held at the American Museum of Natural History. This course was offered to participants in Brooklyn College's K-9 Mathematics and Science Consortium in the summer of 2000, sponsored by a grant from the Dwight D. Eisenhower Title IIA Professional Development Program. The mission of the consortium is to improve standards-based teaching of science and mathematics in Brooklyn elementary and middle schools and to increase the number of certified teachers in these schools. The participants were in-service teachers in the New York City area who were interested in improving their science teaching. Students who satisfactorily completed the course earned 3 graduate credits - which they could apply towards a graduate program in elementary mathematics or science at Brooklyn College or towards their continuing education. Participants in this program are eligible to receive tuition remission for every other course that they take at Brooklyn College School of Education if they are accepted as matriculated students in the elementary mathematics or science education programs as encouragement and support for graduate study in the critical shortage areas of science and mathematics.

The *Workshop in Elementary Education: Science* met for five hours a day for 9 days and incorporated the 3-day Educators' Institute on Space Science at the American Museum of Natural History. The three-day Institute was followed by six 5-hour sessions at the museum led by Brooklyn College School of Education faculty in conjunction with experienced elementary school science teachers. These sessions included guided visits to additional halls, hands-on science investigations relevant to other museum exhibits and student presentations.

Sessions were held in the exhibit halls and in a laboratory classroom at the museum. The course was designed in consultation with Maritza and taught by two experienced elementary science specialists and by myself. The intention of the course was that both formal and informal science education experiences would be incorporated. Most participants were teaching summer school. Throughout the course, students were expected to write a 1-2 page reflection on their experiences each day and how they could incorporate them into their teaching plans for next year. Grades were based on attendance and participation (33%), reflections (33%) and activity presentations (33%). Mini-lesson presentations were expected to be hands-on explorations or active learning activities that related to museum exhibits. Presentations were graded based on quality of lesson, completeness of lesson plan, and presentation. Reflections were graded with an eye to evidence that teachers were thinking of ways to apply workshop skills and materials in their classrooms to help students meet New York City performance standards in science and other areas.

The museum had arranged for Brooklyn College participants to be checked in separately and designated with a uniquely colored packet. Participants were to meet at the dinner hour at specially designated tables as well. The institute began with the Space Show at the new Rose Center for Space; a museum scientist then guided participants through the Rose Center in small groups. The dinner hour allowed time for discussion between participants, scientists from the

Methods of study and the nature of the collaboration between the American Museum of Natural History and Brooklyn College's School of Education for elementary/high school classrooms



For the *Workshop in Elementary Science Education*, qualitative analysis was done of 17 course evaluations and 3 sets of teacher reflections;
The museum also conducted a survey of all 100 Institute participants (of which 20 were from the Workshop).

museum and Brooklyn College faculty in education and physics. Dr. Neil Tyson, Director of the Hayden Planetarium gave a keynote speech outlining the rationale behind demoting Pluto from planetary status. This speech was a well-crafted mixture of evidence, anecdote and persuasion that had teachers riveted.

The second day began with a presentation on approaches to using the museum as a resource, presented by Maritza Macdonald and other AMNH education staff members. Participants then attended two grade-appropriate workshops from among: using starfinders & sundials in the elementary curriculum; music and movement in teaching movement of planets, sun and moon; making and using astronomical models for middle school; technology and printed resources from the National Center for Science Literacy and introducing concepts of astrobiology to middle and high school students. A representative of the faculty from Brooklyn College attended most of the workshops. These workshops were, for the most part appropriate for elementary school teachers, involved teachers actively in working with materials and were well received. Dinner and discussion with Brooklyn College School of Education faculty was followed by presentations by Nicholas Coletto, Director of Math, Science & Technology, of the New York City Board of Education and Sonnet Takahisa, Co-Director, NYC Museum School.

The evening concluded with a "Behind the Scenes Look at the Universe", a special introduction to the new Hayden Planetarium by James Sweitzer and Carter Emmart, Manager for Astro Visualization. Although this presentation continued for nearly an hour past the scheduled end of the evening, almost everyone remained to the end. The personally guided presentations by the directors revealed the science and math behind the new visualization technologies. The ability of the new planetarium to demonstrate the changes in the positions of the stars at different times up to thousands of years in the past or the future, and from any position on the surface of the earth was demonstrated in a guided trip into the past to see the stars as they might have appeared in the year 1 and in an imaginary high-speed walk to the southern hemisphere. We were able to see the constellations visible only from the southern hemisphere emerging over the southern horizon as we sped south. As a follow-up to the morning's workshops, this presentation made the content come alive for the teachers. The presentation on the full-color video capabilities of the theater showed us how a computer could seamlessly join the images from several video projectors to create the illusion of moving in three-dimensional space. Using data provided by the Hubble space telescope the computer created a virtual trip to the edge of the known universe.

On the last day of the Institute participants attended two workshops; one on Rose Center Field Trips and Teaching Guides and one on either Hall of Meteorites and Gems (Middle & High); Literacy Connections for Elementary Grades—Science & Myths or Review of Audio-visual resources for teaching science. Of these, the literacy connections workshop was by far the most valuable for the teachers. The final scientist's presentation on "The History and New Directions in Astronomy" included much interesting information but addressed content that often left the typical elementary teacher participant somewhat "in the dark". One measure of this is that most students did not comment on this presentation in their reflections.

In sum, the Institute provided a number of advantages and a few disadvantages in the context of a course. Some organizational problems unique to being a small group within a large group within an open-to-the public museum necessarily emerged. Allowing students to choose from a number of different workshops meant that not all students had the same experiences. The quality of the workshops varied somewhat, depending on the presenter and there was considerable "down time" due to traveling the long distances between classrooms and exhibits. However, the advantages provided by the interaction with scientists and teachers from other schools more than compensated for these difficulties.

As the class continued on our own, we were able consolidate knowledge by sharing our individual experiences in informal conversations and class discussions in the weeks that followed. As mentioned previously, the intention of the course was that both formal and informal science

education experiences would be incorporated, with an emphasis on the use of museum exhibits and artifacts. Museum artifacts used in the methods course were selected from those that were relevant to the elementary science syllabus. Most had readily available analogous materials that elementary school teachers could access at minimal cost for hands-on observation and experimentation in their classrooms. For instance, after a series of investigations utilizing local and tropical sea shells, students reviewed several relevant exhibits. We began with a hands-on exhibit of shoreline artifacts in the *Nature of New York City* urban-ecology learning center and continued through the formal North American mollusks systematic display where students were excited by finding artifacts similar to the ones they had worked with in each of the different exhibits. We concluded with a visit to the hall of mollusks, a collection of dioramas illustrating the use of mollusk by-products in cultures throughout the world.

On another day students visited the Hall of North American Birds and the Dinosaur Halls after dissecting owl pellets. Owl pellets are available at nominal cost from Carolina Biological and Delta Education among other sources and require no access to specialized lab space or equipment for in-class use. Exhibits and hands-on activities allowed students to use artifacts to develop understanding of food chains; to compare and contrast rodent, bird and reptile skeletal structures and reproductive strategies; to explore the evidence for an evolutionary relationship between dinosaurs and birds; and to gain insight into the use of both fossil and contemporary animal remains to provide evidence about animal interactions within ecosystems. The hands-on dissection of the owl pellets and observation and categorization of the rodent skeletal remains within them prepared students to be more careful and informed observers of the dinosaur fossils on display in the exhibit halls.

Students commented that they had never realized how much you could learn just by looking at things. Many commented that they had often seen bird bones (when eating chicken), but not really thought about them before. As I traveled from group to group, facilitating the dinosaur hall exploration, the teachers pointed out features of the rodent bones and the dinosaur bones. Once we returned to our classroom, we viewed the video *"The Wild Side of New York"* which features the reintroduction of Peregrine falcons into the city. After these varied informal experiences in life and earth sciences we discussed the effects of DDT on contemporary raptor populations, biodiversity, habitat loss and its effects on extinction rates, and explored other environmental science connections to global and local social, legislative and ethical issues. A discussion of the scientific controversy surrounding the various theories for dinosaur extinction provided a segue back to earth materials via the hall of meteorites.

The next day, activities focused on earth materials, beginning with the museum's inspiring collection of meteorites on display in the anteroom to the hall of gems and minerals. As the instructor of this class I was most struck by the high level of interest and involvement demonstrated by the participants after a full day of teaching summer school. The teachers felt free to ask questions and make suggestions to each other in a very constructive way. Group discussions brought forth information based on personal experiences and anecdotes from classrooms and formal educational experiences. Participant comments in the summative evaluations indicated that teachers found learning at the museum was enhanced by the opportunity for sensory interaction with museum artifacts. Teachers realized the value of informal educational sites for teaching in terms of providing an abundance of resources. They gained confidence in their ability to use the museum in their own teaching and learning. While the science methods course was primarily concerned with pedagogical approaches to teaching science, student reflections revealed that substantial science content had been appropriated in the context of this course.

Afterword

I was interested in seeing how the summer experience would be expressed in the actions of participants in subsequent classes. Two students from the summer institute enrolled in an

advanced methods course that I taught the following semester, allowing me to observe them for evidence of application of the experiences in a new context. Two students (who had not participated in the summer institute) wanted to lead the class in an owl pellet dissection for their student-led activity. Both students reacted positively to being given the opportunity to re-visit this task. The students did not dominate the investigations, but assumed the role of facilitator for their groups. Neither student dominated their group. They asked leading questions and helped their colleagues find, observe, categorize and identify the contents of each pellet. In the context of adult learning, the students facilitated learning in the manner that was modeled in the summer course.

Increasing the Overlap: Teacher, Student, and Museum

The summer course provided opportunities for development of increased interrelationship between the museum and college personnel, articulating the links between the formal college setting and the informal educational setting of the museum. The inclusion of the AMNH Institute in the Brooklyn College educational methods course and its continuation on the museum site made the collaborative nature of the course explicit. That this collaboration was a true partnership was manifest by the active participation of museum personnel, including educators and scientists, and college personnel at many levels. Evidence of the CUNY commitment to the college-museum partnership at the instructional and administrative level was provided by the presence of Brooklyn College faculty from education and the sciences and the opening night address by Dean Russell Hochsler.

Evidence of the museum's commitment to the partnership was manifest in several ways. First, the museum offered a yearlong membership to each participant in the program, a clear indication that a long-term relationship is sought. The museum's invitation to participants to become regular docents or summer interns was further evidence of a desire for an ongoing connection between the museum, the college and the students. The museum actively encouraged student comments on exhibits and suggestions for revisions to teacher resources. Students were invited to return for focus groups and follow-up discussions.

These overtures resulted in noticeable response from the participants. At least three students participated in additional museum activities, including follow-up sessions and volunteer opportunities beyond the scope of the institute or the course. The sense of commitment was also made clear by the museum's contribution of resources. Many students commented on the generosity of the museum in providing supplemental reading materials and teacher-resources in their reflections. In addition, students commented that they felt "at home" and "welcome" at the museum. This feeling seemed to be enhanced by the privilege of remaining on the premises after the official closing hour. Students also commented on the welcoming and respectful attitude of security personnel. These intangible "extras" contributed to a sense of community between the students, the museum personnel and the college faculty, myself included.

Further evidence of an ongoing partnership between the museum and the college was provided by the museum's offer to provide resources for courses offered at Brooklyn College in subsequent semesters. Students in the graduate program in elementary science and environmental education revisited the museum as part of their life science course in the fall semester following the summer course. The museum provided a supplemental class text on biodiversity, teachers' guides to the Hall of Biodiversity, a private introduction by the director of professional development and free admission to an IMAX presentation.

The Perspective of the College Geology Instructor

Selected Topics in Earth Science for Elementary School Teachers is an introductory course in earth science that is designed to meet the needs of teachers. The purpose of this course

is to familiarize participants with the basic concepts of the earth sciences and the basic skills of the earth scientist, so that they can teach the elementary-school earth-science curriculum both competently and comfortably. Accordingly the content, that is outlined below, was chosen to reflect the New York State Science Content Standards, particularly stressing those of elementary and middle school:

Properties of Earth Materials

Minerals, Rocks, Fossils, Soil, Water, Atmosphere

Space Science

The Solar System, Asteroids, Comets, Meteorites

Changes in Earth and Sky

Plate Tectonics, Earthquakes, Volcanoes, Weathering/Erosion, Weather

The course ran over a 5-week period in mid-summer, 3 consecutive days per week, 5 hours per day. The 4th week of class meetings were replaced by the 3-day Educator's Institute on Earth Science at the American Museum of Natural History. Although I did not have an outline of what would be covered in this institute, I was informed by another Brooklyn College faculty member that the content of the Museum's Earth Science Institute would approximately mirror the content of the course as described above, and that the specific schedule/syllabus would follow soon. Not knowing the Institute's program, I assumed that there would be a significant amount of space science and that the museum would have better materials and demonstrations to teach this subject. Accordingly, I chose to simply begin teaching my course stressing basic earth science.

The course was daunting in its intense schedule. I was, however, excited to teach this course for the following reasons: 1) it would allow me to build a stronger personal connection with the personnel and resources of the American Museum of Natural History; 2) I could get new teaching ideas from both the museum's educational staff and the students; and, 3) it would allow me to explore interactive activities far more than I could in a standard introductory geology class due to the smaller class size, needs of the students, and willingness of the students to participate in such activities.

The in-class meetings were composed of a lively mix of lecture, demonstrations and activities. In teaching I stressed description, plain-English communication, the need for scientific accuracy in demonstrations, and activity-based learning. This was the delivery that I expected to see demonstrated well at the AMNH. Assessment was based on a midterm and final exam, descriptions and interpretations of group activities, and a final project in which each student presented an activity/demonstration-based lesson centered on a course topic of their choice. Students were required to demonstrate an understanding of the content and apply it to a potential classroom setting. Working groups were self-selected during the first class and did not change throughout the course. Short-answer-exam-based assessment comprised 1/3 of the final grade. Activity-related assessment comprised 2/3 of the final grade.

Summer 2000 was the first time that I taught this, or any other, teacher-specific geology course. Accordingly, preparation for the class took considerable time and effort. Whereas the basic lecture material was at my finger tips, demonstrations and activities had to be created specifically for this class. Considering the intense schedule, it is not surprising that there was little time to consider what was happening in the course the day after next. I looked forward to the Earth Science Institute when for 3 days the educators and scientists of the AMNH would organize and deliver the lessons.

By the end of the week before the Institute was to begin, I had yet to receive any information regarding the session – not even an indication of where we were expected to meet. After a less than ideal start in which my class and I met at what we later found out was the incorrect entrance to the museum, I saw the Institute's program for the first time in my seat with my package of materials:

Day 1: Essentially an introduction and tour of the Museum including a Sky Show at the planetarium, a guided tour of the Cullman Hall of the Universe, and a demonstration of the planetarium's Zeiss projector.
Day 2: An initial guided tour of the Gottesman Hall of Planet Earth followed by two workshop sessions and capped by a dinner and talk by a museum geoscientist.
Day 3: Two "expeditions" to explore aspects of the museum or local area, and a final presentation.

The two formal talks given to the group could not have been more different. The closing remarks were all that I would hope for from the AMNH. The 30-minute presentation about "kicking Pluto out of the planetary family" was engaging, entertaining, informative and seemed far too short. I will be the first to admit that I learned a great deal and was terribly envious of Dr. Tyson's skill as an orator. It could not have contrasted more with the previous day's dinner presentation during which another museum researcher delivered a graduate level lecture on the stable isotope geochemistry of the now obliterated Mt. Mazama volcano to an audience of elementary school teachers. Students at my table initially turned to me to explain the δO vs. δS plots presented on the screen. When I made it clear that I was equally lost, they gradually went back to dinner table conversation, and ignored the speaker. The presenter was well versed in his field, certainly an active geoscientist, but one with no understanding of the needs of this non-technical audience.

Participants were given a choice of 5 workshops in the morning and 5 different workshops in the afternoon on day two, and a choice of 2 of 6 expeditions on day three. The topics were diverse. Expeditions included guided studies of 3 earth/space science halls at the museum and three outdoor activities (glacial geology, weather, orienteering). I allowed students to choose those specific programs that were of most interest to them individually. Due to this decision it was not possible to formally assess students on the material covered in these activities. In essence they were potentially useful, course-related, extra-curricular activities.

My experience with the workshops was mixed. However, I certainly wanted to share my positive experience from a mountain building workshop in which I participated. Accordingly, I began our first class following the Institute by working through the activity that involved slowly colliding layered wedges of play-doh to demonstrate the folding and thickening of sedimentary layers that takes place during mountain building. After that I opened the floor to the students and we openly discussed our experiences in the Institute. Several students praised a workshop designed for elementary students entitled "What's Under My Feet" in which children could turn over objects, open drawers and doors to explore what was around them. The three students that participated in this workshop enthusiastically endorsed this activity and expressed their intent to re-experience this activity with their classes at the museum. Unfortunately my students felt that most of the other workshops were uninspired with too little active learning. The general attitude was that the guided studies of the museum's halls were the most applicable, excluding of course, the tour in which the guide did not arrive.

One student described an activity entitled "How Does the Earth's Mantle Behave?" She detailed how the museum's educators mixed water and corn starch to produce a material that had both the properties of a fluid (leave it alone and it will flow) and a solid (press it with your finger and it will congeal). In this way they attempted to demonstrate the concept that although the mantle is solid, it is still able to flow. This account allowed me to return to a common theme of my course: we must avoid demonstrations that have good intentions but in fact potentially lead to misconceptions. In fact, the behavior of the mantle is the opposite to that of the corn-starch and water: in the mantle, rock acts as a solid if it is left alone, but flows due to stresses imparted to it by temperature gradients. This allowed us to discuss what materials would make a better analogue, with (again) play-doh being the material of choice.

Recommendations

Although not an entirely perfect experience, I am eager to work with the museum again on another teacher education course. The materials available at the museum are invaluable and the relatively minor problems that arose in the summer 2000 institute for me are easily surmountable. The key aspect for improvement is communication and advance preparation. There are essentially three independent groups that I feel need to communicate in order for the Museum Institute experience to be completely effective: the college instructor, the museum's education staff, and the museum's research staff. If I had known the Institute's program several weeks prior to the event, I would have been able to integrate it with the course content and assessment. Instead, the Institute became a relatively non-integrated module within the course. The museum has people with expertise in science communication and teaching (the education staff) as well as in scientific research. Greater levels of communication in planning the institute between these two groups may be helpful, for example, in ensuring that the dinner-time speaker is made aware of the diverse needs of his audience. On the flip side, the scientists may well be able to provide input into the workshops presented by the education staff to ensure the scientific accuracy of models and activities. These kinds of communications between the three groups of people that work together to shape the Institute and teacher education coursework could potentially allow for the development of educational experiences that are exemplary both in terms of science and pedagogy.

Program Head's Perspective

One measure of the success of the methods course at the museum was the number of participants who either entered the master's program in elementary science and environmental education at Brooklyn College or have pending applications. Of the 20 participants, approximately one in three were mathematics specialists. One participant was already permanently certified. Three students had matriculated prior to taking the course. Of the remaining students, six applied for matriculation in the science education program, of whom three were accepted (two enrolled in the fall, one moved to California for personal reasons), and three continue to take courses at Brooklyn College as non-degree students pending meeting admissions criteria. Two participants have applied to take a second summer course at the museum. This high level of interest in pursuing further studies in this program is indicative of substantial student satisfaction with the course.

As program head in the elementary science and environmental education program, I (Eleanor) advise all students in this program. I have had the opportunity to speak with most of the participants in the summer 1999 General Science course *Earth Science for Elementary School Teachers* that incorporated the three-day Educators' Institute on Earth Science. Although students expressed some frustration with the workshops in this institute being designed with secondary level teachers primarily in mind, the overall response to the course has been overwhelmingly positive. Students have referred to the course as "excellent" to me and to others in my hearing.

Overall, I feel that the value of the museum collaboration to the master's program is substantial. In the affective domain alone there are significant intangible benefits. Students appear to appreciate being included in the larger community of the museum, especially given its international reputation for excellence. It is my belief that the prestige of being welcomed into an internationally recognized institution such as the American Museum of Natural History helps to balance the assaults on self-image with which public school teaches in low-income neighborhoods must contend on a daily basis. New York City elementary school teachers work under extremely stressful circumstances. They are held accountable for the low performance of students despite complicated issues such a language barriers and exceptionally high levels of student, faculty, and administrative turnover. Inclusion in the museum "family" seems to help

alleviate some of the stress. There appears to be an increased sense of pride in the students and a more professional attitude. I have noticed a significant increase in apparent student satisfaction with the program overall, and a decrease in complaints. Our increased association with the museum has at the very least coincided with an improvement in student morale.

I believe that this positive influence extends to the faculty as well. Both full-time and adjunct faculty seem to be willing to exert themselves more to travel, meet outside class time and otherwise extend themselves more when admission to the museum as an "insider" is a perquisite of a course. The access to artifacts, publications and museum staff support is seen as an asset by faculty.

What began as an experiment with a single earth science course two summers ago incorporating the AMNH Summer Institute in Earth Science has developed into an ongoing relationship. This first collaboration on a credit-bearing course between the museum and the college was followed by a Brooklyn College education course offered completely on-site at the museum. Based upon the success of the collaboration for science education methods courses a new graduate education elective, *Science Instruction Beyond the Classroom* has been added to the course offerings at Brooklyn College. This course will be offered at the American Museum this coming summer with Maritza Macdonald, the director of professional development as the principal instructor.

Despite a less-than-ideal trial run and the absence of plans for an earth science institute, the collaboration with the museum on the earth science course will continue this summer as well. Instead of the earth science institute, the collaborators have agreed that the museum will provide an on-site laboratory classroom to facilitate utilization of museum exhibits and artifacts in this course.

The Institute Component:

At the end of the institute, participants cited two kinds of learning that reinforced their professional knowledge: learning new concepts of Space and Earth science, and to use rich science resources for learning science.

Analysis of Space Institute findings

The findings on the kind of learning that took place at the institute and prior to the course were derived from analyzing evaluation responses in light of the following three questions:
1) What was the nature of the new concepts that participants acquired at the institute?
2) Were these concepts relevant or required for teaching? and
3) What new processes or technologies had they experienced or learned about at the institute? We included this question because scientific advances and technology are very closely connected and educators are expected to address standards for design, tools, and technologies used in science. For that purpose, the curriculum of the institute exposed participants to the highly technological resources of the Rose Center for Earth and Space, provided demonstrations of on-line resources, and offered a series of workshops making and using simple hand-made models.

The survey asked for responses to the open-ended questions listed above. There were no embedded concept area prompts such as multiple choice questions in this assessment instrument. Responses were based on unprompted recall with limited time and space for response. Therefore the results indicate the minimum percentage of participants who experienced increased content knowledge in each of the eight different areas of earth and space sciences assessed.

To assess the nature and recurrence of concept responses, we grouped and did frequency counts for 100 survey responses (which include the 20 students who participated in the *Workshop in Elementary Methods*). The following chart shows that the institute increased content knowledge inat least eight different areas of space and earth sciences. One participant indicated (he/she) knew the concepts addressed at the institute and mentioned that he has been a participant

in the Museum's Regents variance for Planet Earth. All other responses were connected with the interactions with scientists and experienced teachers and museum educators who use the Museum for teaching.

20% size of the universe
19% evolution of the solar system
14% recent discoveries and theories in space science such as "Pluto is not a planet"
14% models of the universe
10% formation of elements
10% understanding life on earth to search for life in other planets
6% motion of planets
6% formation of stars

1% (I didn't learn new concepts, I have been teaching the Museum's Regents variance for Planet Earth for two years and I know these concepts)

Part of the Museum's approach to professional development is to design experiences that support what teachers as supposed to know and teach. We found that all of these concepts are included in the Science Performance Standards for New York City at the middle and secondary school levels. They are also included in the National Science Standards, and some, such as movement of planets, is included in the elementary level performance standards. These findings reinforce the importance of using rich science and cultural resources – that are usually abundant in urban settings - for teaching adults the content, skills, and attitudes of inquiry they are expected to teach their students.

The final review of findings focused on participants' views of what new resources, approaches, tools, and technologies they had experienced and would like to use with their students. Responses by the same 100 participates were grouped and counted. The following chart shows the results.

29% would use the Museum for teaching science
19% would use models and interaction with real objects
15% would use more visuals and films
12% would make more use of computers and the Internet
8% would use comparisons and contrasts to illustrate points
7% would support students' curiosity
6% would integrate science across the curriculum
4% would include more content specific ideas such as "studies of light"

This last set of findings also correlates with the various approaches connected to the new content pedagogy knowledge reported after the course. In summary, the combination of findings indicate that the institute provided participants with opportunities for them – as adult learners - to interact with real scientists and their work, with scientific tools and resources – and to experience new strategies for learning science. Later on they seem to have been able to solidify these experiences in the courses and its assignments – and later on in the classrooms.

For the future, we plan to continue this type of study. As we deepen collaborations between the Museum and the Teacher Education Programs we feel that it is important to engage in a field of research that documents these collaborations aimed at educators and at students in urban classrooms. We want to know how science-rich institutions leverage the access to resources in urban settings. We want to know how teacher education and scientists come together on behalf of teachers and students. And we want to have enough evidence to show how museum

professional development addresses content knowledge in adults and supports formal learning in colleges and classrooms.

The Teacher Participants

Figure 1 illustrates the methods used in this study to gain insight into teacher thinking and practice. As discussed above, all teacher participants experienced the 3-day Summer Institute at the Museum. The *Workshop in Elementary Methods* ran entirely in the museum even beyond the institute; students in this course participated in the Space Science Institute. In contrast *Selected Topics in Earth Science for Elementary Teachers* ran in the college, other than the 3-day Institute in Earth Science at the museum. Access to teacher thinking was provided by 17 course evaluations and 3 sets of teacher reflections on course activities (a required assignment) for the *Workshop in Elementary Methods*. We were unable to acquire more than the three sets of reflections for analysis in this study. Further, since the reflections were not required for *Selected Topics in Earth Science for Elementary Teachers,* we were not able to analyze as much of these teachers' thinking about the content and pedagogy they learned in this course. However, in interviews with teacher participants from both courses, we gained insights into some thinking and practice, as is described in the sections below.

The first two sections below refer to teachers who participated in the *Workshop in Elementary Methods* since they draw on statements made in the course reflections or evaluations. Included in the second section are also statements made by a teacher participant in this same course during an interview. The final section, entitled Project Impact, draws upon interviews with teacher participants from both courses in the two semesters that followed the summer course experiences. All teachers were asked first, to describe any ways in which they included informal science experiences in their classroom. Second, they were asked to describe how they felt school climate affected their ability to have their class participate in informal science experiences. Finally, teacher participants from the Earth Science course (who had not completed the same course evaluation conducted at the museum as the Workshop participants had) were asked to describe what they thought of the Summer Institute at the Museum.

"The Real Thing" or Cultural Artifacts at the Museum

This section refers to statements made in course evaluations and reflections by teachers who participated in the *Workshop in Elementary Methods*. Thirteen of the seventeen teacher participants, who completed course evaluations for the summer methods course held at the museum, commented in their course evaluations on the fact that one of the museum's greatest virtues was the opportunity it afforded them to come into contact with "the real thing" – whether that meant rocks and minerals or images of the constellations photographed by powerful telescopes. Meaningful learning seemed to take place when teachers were provided with access to the wide range of artifacts on display in the museum that represent the tools for and the products of scientific exploration and understanding. Here, I highlight a handful of comments made by teacher participants.

One teacher wrote in her evaluation of the methods course that was held at the museum: "The biggest difference (between the college and the museum) is the amount of resources we used at the museum... We saw samples of things that no classroom in a college would have, like dinosaurs and mammals."

For her, the wealth of museum resources that she had had access to in her summer course experience was an important factor in her learning. From her standpoint, this richness of resources validated her coming to the museum for her class as opposed to going to the College. Her experiences with the "samples of things that no classroom in a college would have" were powerful and intriguing enough to make her feel that what she appropriated from her contact with

these samples could not have been substituted by other classroom experiences. Another teacher echoed these sentiments in her evaluation:
"The course increased the resources we have available to us by making us aware of them. Awareness is the key!"
Not only were there more resources available at the museum compared to the college, the museum resources were available to teachers and their students during the school year. This is a significant realization.

An increase in confidence was facilitated by the myriad museum resources for Janet, another teacher participant. She wrote in her evaluation for Eleanor's course: "It gave me the confidence to explore more materials - that I would not have used before. It enabled me to understand concepts that I had no idea about."
Janet's level of confidence in teaching science is connected to her experiences handling relevant materials. There is a vast difference between constructing meaning using mere representations of materials (like books and pictures) and constructing meaning using the actual materials. In Janet's case, this difference is key; she sees her explorations with a wide range of materials in the museum as being instrumental in her understanding of the concepts that relate to the materials. From her comments, it seems that Janet experienced doing science in the summer course at the museum. Doing science requires access to the materials and tools that scientists use to understand concepts as well as to opportunities to think and talk about ideas and questions in guided settings.

For Olivia, the boost in her confidence level that resulted from her summer experiences translates to a plan for her classroom instruction. What she did in the course provided a model for what she could have her students do in the classroom. She writes in her course reflections: "The categorization of rocks vs. minerals is another sure fire way to have students find out for themselves the differences between the two. By sight and touch, they can begin to realize the process that geologists use to discriminate between the two. I will implement this hands-on experience in my classroom. Although I have rocks and minerals in my classroom, I never felt confident enough to instruct students in this way. I felt I didn't know enough of this subject to instruct my students effectively."

One outcome of the summer course at the museum was that Olivia was empowered to use existing resources in her classroom. Her experiences at the museum with handling samples of rocks and minerals mediated her understanding of how they differ so much so that she now recognizes the need for such artifact-mediated learning if the goal is to truly experience doing science. She recognized that although access to real-world artifacts may be more limited in the classroom, there was nonetheless some space to emulate in the classroom some of what she had enjoyed doing at the museum.

The museum, in providing teachers in these courses with access to the "real thing", seemed to provide a window to more dynamic ways of thinking about themselves as science learner and practitioner. Further, the museum artifacts were contextualized by discussion and activity focusing on learning and teaching science. Together, they mediated teacher learning and thinking about science and teaching science.

Teacher Learning

Teacher participants voiced opinions that point to two key areas of knowledge growth. These were, first, strategies for facilitation of students' museum-mediated learning and, second, a deepening of understanding about various scientific phenomena and ideas in concert with growth in appropriate pedagogies.

James spoke about his learning during the science methods summer course in an interview: "I've been fascinated by the museum for a long time. But I never really knew what to

do when I got there...I've learned some things about developing...different projects so that when students come there they'll have questions instead of just saying I'll look at that, I'll look at that." If students visit the museum with their own personal agendas, where they come prepared to resolve some questions, James feels they would enjoy the experience and find it meaningful. He added that he felt that most of the teachers in his district – which is the same district that he went to school in – were not trained in what they or the students could do when they go on a trip. For them, "a trip is just a day out in the field ad hopefully you'll learn something."

In his current position as learning leader in a school in District 16, James told me during the interview that he had informally "passed along the resources" to other teachers by suggesting ways of adding interest and meaning to a lesson on the concept of species. He suggested to the teacher integrating the notion of interdependence of species with a focus on problems involving urban animals, such as squirrels, rats, and so forth. He commented that he had borrowed from discussions that he had participated in during the course when they had discussed marine food webs. His own experiences thinking about the ramifications of industry on these interdependencies, as well as an introduction to the "wildlife" in New York (through video as well as a workshop in Central Park) led him to the recognition that in order for a concept to be meaningful, it needs to interact with issues and examples that are meaningful to the student.

Other teacher participants wrote in their course reflections about other principles they felt were important to consider when planning a museum trip. Michelle wrote in her course reflections about the importance of being selective when it comes to planning for a museum trip: "Moreover, it is important to select the appropriate level and focus on a limited amount of displays instead of overwhelming the students..."

Ann commented on the significance of the collaborative aspect of the course: "Our group was one of the most cohesive teams I have ever worked with....Most importantly, we learned from each other...The experience at the Museum gave us ideas and an understanding of ways to present them to our students. It also made us aware that preparation is the key to successful pedagogy...It is vital that you are aware of the world around you."

A combination of various factors seemed to have made this course experience a particularly powerful one for Ann. The fact that the course was held at the museum, which meant that the teacher participants had the opportunity to visit museum exhibits many times, was important. Associated with this was the fact that teachers became familiar with museum staff and with the museum itself. The teachers spent the equivalent of a semester's class time in the museum, surrounded by displays, artifacts, and exhibits. In short, the class was conducted in a place that explicitly values, and perhaps represents, "the world around you". Further, the fact that the course was structured so that teachers shared opinions and lesson plan ideas with each other repeatedly was important.

The second key area of knowledge growth resulting from these courses was content-pedagogy, as evinced by the three sets of course reflections I was able to read. Content and pedagogy were tightly linked in the minds of James, Olivia, and Ann – all participants in the summer methods course that was conducted at the museum. They almost always wrote about what science content they learned in partnership with their thinking about how they would bring it into the classroom or how their students would benefit from the same learning experience. Here, I highlight just two examples of teacher thinking relating to content-pedagogy.

Olivia's experience during a rock-sorting activity in the museum classroom was positive. She considered the importance of having this type of experience before attempting to attach unfamiliar labels (the names and definitions) to the rocks. She came up with new extensions of the activity that she would like to try with her own students, such as having her students note color variations and relating that to chemical composition, having students determine density and identify the rocks based upon density, and so forth. She wrote in her reflections about an activity at a museum exhibit in which she participated after having completed the classroom activity:

"We then went to the hall of meteors and the hall of gems and minerals where we were asked to try and find our rocks. Mine was formed when a meteor struck the Earth. It was not part of the meteor but instead it was heated up by the meteors when they hit Earth and then it cooled rapidly thus getting its round shape. We were also asked to find a rock that interested us and to become an expert on that rock. I picked Spodumene. It's chemical make-up is $LiAlSi_2O_6$ – one part both lithium and aluminum to two parts silicon and six parts oxygen. Its name comes from the Greek word meaning burnt to ashes. This was a nice activity except that I kept having trouble finding information on the first two rocks that I decided to look for, so I finally settled on a rock that had a lot of (text) next to it so that I could finish the assignment. I think I would like students to get rocks from different groups (calcium, carbon, etc.) so that we could go back and have a discussion on the different types of rocks (each cold have their own rock as long as it came from the same group). I would probably group students together instead of having them work alone so that everybody would have help finding information on their rock."
It is clear that her understanding of rocks in general and of her rock in particular has deepened through her participation in these activities. She does not, however stop at learning the science content. The relationships between what she learned, how she learned it and how she would implement this in her own classroom are tight. Having experienced the learning firsthand, she is in a position to critique the teaching strategy, to make modification in her own mind and come up with a lesson plan that she feels would be more appropriate for her students. Olivia, like Ann and James, does not segregate science content from pedagogy in her thinking. The result was her constant assessment of the teaching methods used in the course and of the museum displays she viewed in light of what science she was learning.

Ann sees the relationship between classroom science activities and museum visits as complementary experiences for her students. She wrote in her reflections:
"This (Gottesman Hall of Planet Earth) made me realize how essential it is to have students see rock formations, craters, and minerals to get a realistic visual of the differences. I would use this hall as a culmination of a thematic unit revolving around the study of the Earth's surfaces...They can see that rocks they were examining (in hands-on activities in the classroom) come from a much larger surface and (these materials) make up the earth and the universe."
For Ann, the museum provides the larger context and the broader sample of real-world examples while her classroom provides the in-depth, hands-on study of a smaller set of real-world examples. She learned about rock formations, craters and minerals at the museum from observing the museum exhibits and from the activities that she participated in during class time at the museum. These two sets of experiences led to her construction of classroom curriculum that was linked to museum displays in an important way.

Learning new strategies on how to use the museum as a resource, learning about scientific concepts and constructing classroom curriculum inspired by the course conducted at the museum were three key outcomes of this course for these teachers.

Project Impact on Teaching

We were able to reach four teachers who had taken Wayne's course and six teachers who had taken Eleanor's. One of these six teachers was James, who is a learning leader but does not have his own class. One of these individuals, Grace, had taken both courses, making the total number with whom we communicated nine. Of these nine teachers, eight taught in grades K-8 and one taught high school biology.

Testing and Other Perceived Constraints

Four teachers spoke at length about their plans to take their class to the museum or to other informal science learning locations such as the Botanical Gardens in April or May, once the rounds of testing were completed at their respective schools. School administration, they felt,

would not support taking trips – perceived as nonacademic activity – in face of the need for concentrated test preparation, perceived as in-class activity.

Susan, who said that she had not taken her class to the museum since she took the methods course there last summer, commented:

"The climate at my school is...test-oriented. Although we are encouraged to include social studies and science in our programs, we are required to teach reading and language arts for the first three periods of the day and two periods of math. There is the sense that the children must be prepared for the test, yet at the fourth grade level they are also required to take a science test. I don't believe our administrators realize how important the other curriculum areas are to children's mathematical and language skills."

In Susan's school, the predominant view seems to be that children need to spend most of the day learning and preparing for the tests – which focus on language arts and mathematics. Further, the view is that the way in which children can best prepare for these teats is by in-class activity. The fact that there is a required science test at the fourth grade level does not receive as much attention, perhaps because that is not an immediate issue.

Edward and Janelle both teach at SURR schools (Schools Under Registration Review), which are designated by the New York State Board of Regents as low-performing schools. Such schools are strictly required to devise and implement strategies designed to produce measurable improvements in the academic performance of their students. They felt that as such, the possibility of trips to informal science centers for their students anytime before May was precluded. Edward added that there was a vigorous turnover of teachers and principals at his school, making it difficult to get a sense of stability and a sustained outlook on issues such as the value of informal science experiences. Principals of each school gave teachers the clear message that teachers were to concentrate on academics. Edward also spoke of his desire to have his class gain more access to the Internet so that they could visit the museum website and other such websites. He added that he thought most of his students and their parents were unfamiliar with the museum and such Internet access would be helpful in increasing exposure and building student identity as museum visitors and therefore, a connection to museum culture. Janelle mentioned that her students did go to a play in February; however since this was perceived as being clearly associated with language arts skills, it was not perceived as being "nonacademic".

Grace teaches a gifted fifth grade class in a K-5 school. She plans on taking her students to the Gottesman Hall of Planet Earth at the museum in April. She found that her summer experiences there helped her to "understand a lot more Earth Science" and felt that her 28 students would similarly benefit from the visit. She felt that a museum visit would enhance students' academic ability as long as the instructor visits the museum prior to the trip and focuses on a few components "instead of having the students do a free walk around the displays."

For Susan, Edward, Janelle, and Grace, who teach in different schools with different populations, the common thread was that testing constrained their ability to take their students outside the classroom. Only one of these four teachers, Edward, talked about trying to conduct science explorations in the schoolyard. It seemed that for the others, taking the children outside the class translated to field trips to the museum or some similar setting. The question becomes: what view of informal learning centers do teachers have? Most of the teachers I spoke to in this study did not disagree with the assumption that a trip to the museum or to any science setting beyond the classroom was "nonacademic" or at least not essential in the pursuit of a sound education in science. Further, the fact that most teachers did not mention the potential that class trips to informal science centers have for student learning in language arts and mathematics points to a need for greater discussion of the interdisciplinary value of visits to informal learning centers such as the museum of natural history. Finally, despite the fact that one of the workshops that many teachers participated in at the Institute focused on technology applications, only one of

them (Edward) made mention of how internet access could be helpful in either their own lesson preparation or in classroom activity.

Teachers who visited informal science settings with their classes

Stella, who teaches ninth grade and Advanced Placement Biology, Carrie, who teaches 6th and 7th grades, and Alison, who teaches 8th grade earth science in a private school had all taken students to informal science centers in the fall. Stella and Carrie had taken Wayne's course and Alison had taken Eleanor's course the previous summer. Among the places that Stella had taken students to in the past were the Brooklyn Botanical Gardens, the Aquarium, the Museum of Natural History, the Cold Springs Harbor DNA Laboratory, and to outdoor settings near the school. Stella did not feel supported in her efforts to include informal science learning by the school administration. Transportation issues, paperwork, time constraints, substitute shortages, and low parent interest were all mentioned by her as representing significant obstacles. Stella also spoke of her sense that there was an underlying feeling amongst many faculty and administrators at her school that organization of field trips for students at their school was a wasted effort. Her sense is that many of her colleagues perceive a difference in museum culture versus their students' culture. This tension between the perception of the museum as "high" culture and the students as consumers of "low" culture angered Stella, who perseveres in her own efforts to have her students experience science in a variety of settings. She felt that she gained in many ways from the summer institute at the museum, for example, she was inspired by the moon journals discussed at one of the Institute workshops she attended and created a tree-log journal assignment for her students.

Carrie took her students to the Aquarium. She was very familiar with the Aquarium since she used to be an animal keeper there. She talked about how it was extremely important for the teacher to really know the place; she felt safe at the Aquarium since she knew the staff there and knew they would be helpful. She admitted that the trip and her in-class curriculum may not have been tightly connected. Although she had a sound idea of focusing her students on the connections between the physical and life sciences (since she taught physical science), she did not plan a rigorous series of activities that focused on this relationship. There was no clear relationship between what the students did in the classroom and what they were doing at the Aquarium. The question becomes: what did students learn from the Aquarium visit and in what ways were they able to reinforce what they learned after their trip? The trip, Carrie mentioned, was "just a reason to go to the aquarium" and have some fun. She mentioned that she is considering a visit to the Museum of Natural History and the Central Park Zoo but that transport was an issue. The Aquarium was near the school, which made it possible to use the subway and be back before the school day ended.

Alison spoke about the fact that she would not have taken her 8th graders to the Museum of Natural History in November, during a unit on rocks, if she had not participated in the museum course in the summer. She took her students to the Hall of Planet Earth and also visited the minerals hall. She allowed her students to view other halls and see the IMAX film as well. She felt that the trip was successful largely because each student had something to do as they viewed the exhibits. She mentioned that she modified and used materials derived from the summer course. She passed on some museum materials to a colleague at her school who later took her students to the Hall of Human Biology and Evolution at the museum. Perhaps not surprisingly, given the fact that theirs is a private school context, both Alison and her colleague were able to act upon their desire to take their classes to the museum when they wanted.

Stella, Carrie, and Alison all deal with different issues as they work in different contexts and with different age groups. Consequently, although they all took their classes to informal science centers, the ways they approached these trips were, not surprisingly, different.

Outcomes of The Museum-College Collaboration

The findings after the institute but prior to the course seem to reflect a different dimension of the perspectives reported after the course and in the school. After the course, participants cited new pedagogical approaches and felt grounded by knowing and using "real objects." At the end of the institute, participants cited two kinds of learning that reinforced their professional knowledge: learning new concepts of Space and Earth science, and to use rich science resources for learning science. Teaching science and methods for using resources for teaching were reported after the course that followed the institute. These complementary findings seem to indicate that the combination of professional development that addresses knowledge of content and technologies when followed with a formal course on science methods and curriculum resources in museums has impact that can be found later on in classrooms. As a result, it appears that coordinated interaction of the informal and the formal gives teachers new knowledge of how they learn and how to use those insights and resources for teaching. A model worth exploring as we try to address science content knowledge and pedagogical content knowledge in impoverished urban schools by identifying and using rich resources, such as Museums, parks, zoos, and botanical gardens.

Recommendations

The key constraint that several elementary and middle-school teachers talked about was school administration's perception that firstly, science was not a priority, and secondly, that science-related trips were not "academic". Ironically, Edward and Janelle – both of whom teach at a SURR school – talked about their sense that their principals did not view trips favorably since they take time away from test preparation. More needs to be done to involve school administrators in Institutes and other events at the Museum of Natural History in order for them to recognize that such informal science experiences can, in fact, help in test preparation if the instructor prepares for and follows up the visit with appropriate classroom activity and that language arts, mathematics, social science as well as science can all benefit from class visits to informal science learning centers.

Secondly, discussion of the value of informal science learning needs to become a part of teacher education programs in order for teachers to be aware of the resources such centers offer to teachers and their classes in the way of professional development, curriculum enrichment and exciting activity. Internet access to resources such as the museum website needs to be a significant resource that is highlighted in teacher education programs (Miele, 2000.) In order to prepare public school teachers to teach science effectively in urban settings, it is important that one of the goals of the teacher education program be to help teachers see the rich resources that exist and that are easily accessible to them for teaching purposes. One of us (Eleanor) has incorporated such a discussion into pre-service teacher education in the context of the introductory mathematics, science and technology educational methods course at Brooklyn College (Miele, 1998.)

Finally, Stella's and Edward's sense of a tension in the perception of the museum as a place that is continuous with other student experiences points to a need for continued work to expand views on what the museum offers to ***all*** students. Collaborations such as the one described in this study should continue to grow in order to reach increasing numbers of teachers and school administrators. Continued work with families (which was not the focus of this study but which the museum focuses on in other programs) is also important in order for students to be familiar with museum settings and to identify themselves as museum visitors.

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